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CONCENTRATION OF TRIBUTYLTIN IN THE SURFACE MICROLAYER OF NATURAL WATERS

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Executive Summary

High concentrations of the very toxic antifouling agent tributyltin have been found in 24 surface microlayer samples in a survey of 74 locations in Ontario, Quebec, Michigan and New York State. In 6 of these 24 locations the concentration of tributyltin in the surface microlayer exceeded the 24-hr LC-50 value for adult rainbow trout. The most heavily contaminated area was the mouth of the Moira River at Belleville, Ontario, where the concentration of tributyltin in the surface microlayer was 42 times the 24-hr LC-50 value for trout. The concentration of tributyltin in the surface microlayer was occasionally so much greater than that in subsurface water that the microlayer contained a significant amount of tributyltin relative to that in the whole depth of subsurface water. Similar findings were observed for the less toxic degradation products of tributyltin - dibutyltin, monobutyltin and inorganic tin.

Management Perspective

If high concentrations of tributyltin, or any toxic substance, prevail in surface microlayers for extended periods of time, they may (i) pose a significant hazard to aquatic organisms which spend all or part of their lives at the air-water interface, and (ii) significantly change estimates of amounts of chemicals in aquatic ecosystems. It may be that such loadings have been seriously underestimated. We are presently monitoring the concentrations of chlorinated hydrocarbons in the surface microlayer of the Niagara River over a one year period to determine whether or not the microlayer makes a significant contribution to the loading of toxic substances from the Niagara River to Lake Ontario.

Concentration de tributylétain dans la microcouche superficielle des eaux naturelles

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Sommaire

De fortes concentrations de tributylétain, un agent anti-salissures très toxique, ont été observées dans 24 échantillons prélevés dans la microcouche superficielle à 74 endroits en Ontario, au Québec, au Michigan et dans l'état de New York. A six endroits, la concentration de tributylétain dans la microcouche superficielle était supérieure à la CL50 de 24 h pour la truite arc-en-ciel adulte. La zone la plus polluée se trouvait à l'embouchure de la rivière Moira à Belleville, en Ontario, où la concentration de tributylétain dans la microcouche superficielle était 42 fois plus élevée que la CL50 de 24 h pour la truite. Parfois, la concentration de tributylétain dans la microcouche superficielle était significativement beaucoup plus élevée que celle présente dans toutes les eaux subsuperficielles.

Des conclusions semblables ont été tirées pour les produits de dégradation moins toxiques du tributylétain-dibutylétain, du monobutylétain et de l'étain inorganique.

Perspectives de gestion

Si le tributylétain, ou toute autre substance toxique, est présent dans les microcouches superficielles en fortes teneurs pendant de longues périodes, il peut (i) constituer une menace sérieuse pour les organismes aquatiques qui vivent, en partie ou en totalité, dans l'interface air-eau, et (ii) modifier notablement les estimations des teneurs en produits chimiques des écosystèmes aquatiques. Il se peut que ces teneurs aient été fortement sous-estimées. Nous surveillons actuellement les teneurs en hydrocarbures chlorés de la microcouche superficielle de la rivière Niagara pendant un an afin de déterminer si la microcouche joue un rôle important dans l'apport de substances toxiques dans le lac Ontario.

ABSTRACT

High concentrations of the very toxic antifouling agent tributyltin have been found in 24 surface microlayer samples in a survey of 74 locations in Ontario, Quebec, Michigan and New York State. In 6 of these 24 locations the concentration of tributyltin in the surface microlayer exceeded the 24-hr LC-50 value for adult rainbow trout. The most heavily contaminated area was the mouth of the Moira River at Belleville, Ontario, where the concentration of tributyltin in the surface microlayer was 42 times the 24-hr LC-50 value for trout. The concentration of tributyltin in the surface microlayer was occasionally so much greater than that in subsurface water that the microlayer contained a significant amount of tributyltin relative to that in the whole depth of subsurface water. Similar findings were observed for the less toxic degradation products of tributyltin - dibutyltin, monobutyltin and inorganic tin. If high concentrations of tributyltin or any toxic substance prevail in surface microlayers for extended periods of time, they may (i) pose a significant hazard to aquatic organisms which spend all or part of their lives at the air-water interface, and (ii) significantly change estimates of amounts of chemicals in aquatic ecosystems.

RÉSUMÉ

De fortes concentrations de tributylétain, un agent anti-salissures très toxique, ont été observées dans 24 échantillons prélevés dans la microcouche superficielle à 74 endroits en Ontario, au Québec, au Michigan et dans l'état de New York. A six endroits, la concentration de tributylétain était supérieure à la CL50 de 24 h pour la truite arc-en-ciel adulte. La zone la plus polluée se trouvait à l'embouchure de la rivière Moira à Belleville, en Ontario, où la concentration de tributylétain dans la microcouche superficielle était 42 fois supérieure à la CL-50 de 24 h pour la truite. Parfois la concentration de tributylétain dans la microcouche superficielle était significativement très supérieure à celle des eaux subsuperficielles. Des conclusions semblables ont été tirées pour les produits de dégradation moins toxiques du tributylétain- dibutylétain, du monobutylétain et de l'étain inorganique. Si le tributylétain, ou toute autre substance toxique, est présent dans les microcouches superficielles en teneurs élevées pendant de longues périodes, il peut (i) constituer une menace sérieuse pour les organismes aquatiques qui vivent, en partie ou en totalité, dans l'interface air-eau, (ii) modifier sensiblement les estimations des teneurs en polluants chimiques des écosystèmes aquatiques.

INTRODUCTION

The surface microlayer of natural waters, which contains a hydrophobic film of long-chain fatty acids, alcohols, esters and other chemicals, is thought to be important in the aquatic environmental distribution of hydrophobic pollutants. The thickness of the surface microlayer is operationally defined by the type of collector used (Garrett 1965; Harvey 1966; Harvey and Burzell 1972; Baier 1972; Hatcher and Parker 1975), and values from 60 um to 200 um are common. Several articles have demonstrated higher concentrations of contaminants in surface microlayers relative to subsurface waters (e.g., Eisenreich 1982; Armstrong and Elzerman 1982; Meyers and Kawka 1982, and references therein). This finding has important implications for (i) organisms which spend part or all of their lives at the air-water interface, and for (ii) estimates of amounts of toxic chemicals in aquatic ecosystems. In addition, it has been shown that the kinetics of some reactions may differ between the surface microlayer and bulk solution (Valenty 1979), and the possibility exists for enhanced sunlight photolysis of chemicals in surface microlayers since there is little attenuation of sunlight compared to the attenuation experienced in penetration to greater depths in the water column. Finally, the volatilization of contaminants from water, and deposition of contaminants to water from the atmosphere, of course take place at the air-water interface.

In the course of a cross-Canada survey for the highly toxic antifouling pesticide tributyltin in water and sediment (Maguire _et al._ 1986) we collected samples of the surface microlayer from 74 locations, mainly in Ontario, but with some from Michigan, New York State and Quebec. This article compares concentrations of tributyltin, and its much less toxic degradation products dibutyltin, monobutyltin and inorganic tin, in the surface microlayer with those concentrations previously reported for subsurface water (Maguire _et al._ 1986).

EXPERIMENTAL SECTION

For brevity, each of the n-butyltin species is referred to here as though it existed only in cationic form (e.g., Bu_3Sn^+). This formalism is not meant to imply exact identities for these species in water.

Materials

Bis(tri-n-butyltin) oxide, di-n-butyltin dichloride, n-butyltin trichloride and tin were from Ventron (Danvers, MA, USA). n-Pentylmagnesium bromide was prepared from readily available chemicals. 2-Hydroxy-2,4,6-cycloheptatrien-1-one (tropolone) was from Aldrich (Milwaukee, WI, USA). All organic solvents were pesticide grade from

Caledon (Georgetown, Ont.). Sulfuric and hydrochloric acids were reagent grade, but the HCl was washed with a solution of tropolone in benzene to remove traces of inorganic tin. Water was organic-free.

Butylpentyltin ($Bu_nPe_{4-n}Sn$, where n LT 4) standards were prepared by standard Grignard techniques (Maguire and Huneault 1981; Maguire and Tkacz 1983) which do not result in redistribution of alkyl groups.

Sample Collection

Samples of subsurface water and surface microlayer were taken from the 74 locations shown in Table 1. The small boats used in sample collection were not painted with tributyltin-containing antifouling paint.

As reported previously (Maguire et al. 1986), samples of subsurface water (8 L) were collected from a depth of 0.5 m in amber glass bottles, and the contents were acidified to pH 1 and stored at 4 degrees C until extraction. These preservation conditions are effective over a period of at least three months (Maguire 1982). Surface microlayer samples of approximately 100 mL were collected with a glass plate sampler (Harvey and Burzell 1972) and preserved in the same way as the subsurface water samples.

Sample Analysis

The methods of analysis for water are documented elsewhere (Maguire and Huneault 1981; Maguire et al. 1982). In essence, they involve extraction of Bu_3Sn^+, Bu_2Sn^{2+}, $BuSn^{3+}$ and inorganic tin from acidified water samples with the complexing agent tropolone dissolved in benzene, pentylation of the extract to produce the volatile mixed butylpentyltin derivatives, $Bu_nPe_{4-n}Sn$, purification by silica gel column chromatography, and gas chromatographic determination of the derivatives by packed column gas chromatography with a quartz tube furnace atomic absorption spectrophotometric detector (Maguire and Tkacz 1983). Considering that a fairly specific detector for tin was used in the analyses, identities of the butylpentyltin derivatives were deemed to be confirmed by co-chromatography with authentic standards on two column packing materials of very different polarity.

In the quantitation of the analytes, use was made of appropriate reagent blanks. The results reported in this article are all above the limit of quantitation (LOQ), which is defined (Keith et al. 1983) as the reagent blank value plus ten times its standard deviation. In practice, for our work this is equivalent to stating that a chromatographic peak was not accepted as real unless it was at least 2-3 times as large as any corresponding peak in the reagent blank. Recoveries of the three butyltin species from spiked water samples at 1-10 mg Sn/L varied from 96 +/- 4 to 103 +/- 8 % (Maguire and Huneault 1981). Recoveries of Sn(IV) from water at pH 5-8 were poor (35 +/- 23 %), probably because of the formation of unextractable SnO_2 (Maguire et al. 1983). Although Sn(IV) was the only inorganic tin species for which recoveries were determined, the tin present in our water samples is reported as total inorganic tin, since any Sn(II) which might have been present would likely have been oxidized to

Sn(IV) during pentylation. The concentrations of butyltin species and inorganic tin in water reported in this article have not been corrected for recovery.

RESULTS AND DISCUSSION

In Canada, tributyltin has been found mainly in harbours, marinas and shipping channels (Maguire 1986; Maguire _et al._ 1986), which is consistent with its use as an antifouling agent. In subsurface water its concentration in some locations was high enough to cause concern with regard to chronic toxicity or effects in sensitive organisms. It has also been found in mg/kg concentrations in some harbour sediments, but the toxicological significance of sediment-associated tributyltin is unknown.

Table 1 compares concentrations of the three butyltin species and inorganic tin in the unfiltered surface microlayer with those concentrations which have previously been reported for unfiltered subsurface water (Maguire _et al._ 1986). The comparison is done only for those 74 locations at which both "compartments" were sampled.

The most important species to consider is tributyltin since the toxicity of butyltin species declines substantially with decreasing number of butyl groups (Davies and Smith 1980). In the surface microlayer, tributyltin was determined reliably (_i.e._, at concentrations greater than its limit of quantitation) in 24 of the 74 samples. Concentrations ranged from 1.9 to 473 ug Sn/L, and in general were much higher than concentrations which have been reported in subsurface water in Canada (Maguire _et al._ 1982; Maguire _et al._ 1985; Maguire 1986; Maguire _et al._ 1986). Concentrations of tributyltin in the surface microlayer were also generally substantially higher than those found in the microlayer in an earlier, much more limited, study (Maguire _et al._ 1982). At all 24 locations in question in this study, the concentration of tributyltin exceeded the 12-d LC-100 value of 1.8 ug Sn/L for rainbow trout yolk sac fry (Seinen _et al._ 1981). In 6 of these 24 locations (119, 130, 196, 199, 211 and 232) the concentration of tributyltin exceeded the 24-hr LC-50 value of 11.3 ug Sn/L for adult rainbow trout (Alabaster 1969). Indeed, the concentration of 473 ug Sn/L in the surface microlayer of the Moira River at Belleville is 42 times higher than the 24-hr LC-50 value for adult rainbow trout. It should be borne in mind, however, that the concentration of any toxic substance in the surface microlayer may vary significantly with time because of turbulence.

Examination of Table 1 also reveals that the surface microlayer can be used as an indicator, albeit imperfect, of contamination of subsurface water. For example, tributyltin was determined in the surface microlayer at 11 locations in which it was not found in subsurface water.

No attempt was made in this work to determine the partitioning of tributyltin between suspended solids and "solution" since the solids/water partition coefficient (Kp = 3×10^{3} ug/kg/ug/L) at a suspended solids concentration of 10 mg/L indicates that most of the tributyltin is associated with the aqueous phase of the water column and very little is adsorbed onto suspended solids (US Navy 1984). For the purposes of this work, therefore, it is assumed that all the tributyltin in the surface microlayer and the subsurface water is bioavailable and potentially toxic to aquatic life.

Table 2 shows that the ratio of the concentration of tributyltin in the surface microlayer to its concentration in subsurface water ranged from 41 to 47300 for those 10 locations at which tributyltin was determined with confidence in both the surface microlayer and subsurface water. The observation of such high ratios prompted an estimation of the relative amounts of tributyltin in the surface microlayer and subsurface water. This was done by (i) considering a sample of water of length, width and depth A, B and C m, respectively, upon which rests a microlayer D m thick, (ii) supposing that the concentration of tributyltin is X ug Sn/L in the surface microlayer and Y ug Sn/L in the subsurface water, and (iii) assuming that Y is invariant with depth. The ratio of the amount in the surface microlayer to the amount in subsurface water is XD/YC. Values for the ratio of amounts were calculated with the data in Table 1, water column depth from the Appendix, and with D = 6×10^{-5} m (determined at several locations), and are shown in Table 2. In the majority of cases the ratio was small. Notable exceptions were at Belleville and Thunder Bay (1), at which locations the amount of tributyltin in the surface microlayer was 71 and 6 %, respectively, of the amount in the whole depth of subsurface water.

Tables 3-5 show similar calculations for the less toxic dibutyltin, monobutyltin and inorganic tin species. Ratios of concentrations of species in the surface microlayer to concentrations in subsurface water ranged from 100 to 34400 for dibutyltin, from 2 to 2640 for monobutyltin, and from 1.8 to 20000 for inorganic tin. The amount of material in the surface microlayer exceeded 5 % of that in the whole depth of subsurface water at 2 of 5 locations for dibutyltin, 0 of 14 locations for monobutyltin, and 3 of 34 locations for inorganic tin. The most notable results were (i) for Turkey L. (3), in which the amount of dibutyltin in the surface microlayer was 52 % of the amount in the whole depth of subsurface water, and (ii) for Belleville, in which the amount of inorganic tin in the surface microlayer at the mouth of the Moira River was 30 % of the amount in the whole depth of subsurface water.

In conclusion, this article has demonstrated the common occurrence of high concentrations of tributyltin and its degradation products in surface microlayers of natural waters. What is needed is a study of the temporal fluctuations of concentrations of toxic substances in microlayers. This would be important from the point of view of toxicity of such substances to organisms that spend part of their lives at the surface of water, and it would be important from the point of view of the loadings of toxic substances from rivers to lakes. It may be that such loadings have been seriously underestimated. We are presently monitoring the concentrations of chlorinated hydrocarbons in the surface microlayer of the Niagara

River over a one year period to determine whether or not the microlayer makes a significant contribution to the loading of toxic substances from the Niagara River to Lake Ontario.

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Table 1. Concentrations (ug Sn/L) of Butyltin Species and Inorganic Tin in Unfiltered Subsurface Water and Unfiltered Surface Microlayer*

No.	Location	Subsurface				Microlayer			
		Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin	Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin
	ONTARIO								
112	Wabigoon R. at Dryden			0.05	4.20				
115	Wabigoon R. (2)	0.01	0.12	0.25	2.90				
116	Clay L. (1)			0.19	2.10				
117	Clay L. (2)		det.	0.03	2.11				
118	Wabigoon R. (3)			0.15	0.41				
119	Thunder Bay (1)	0.01	0.02		8.29	20.9	37.9	46.5	74.3
120	Thunder Bay (2)	0.08	0.01	det.				1.4	23.9
121	Thunder Bay (3)		0.07	0.15	0.11				
122	Kaministiquia R.				0.22	4.4	1.8	3.4	95.9
123	Nipigon R.	0.64							
125	Marathon (1)			0.05	1.08				
127	Marathon (3)	0.02			0.16				10.0
128	Turkey L. (1)	det.			0.03				38.5
129	Turkey L. (2)	0.09			0.06		365	30.2	
130	Turkey L. (3)	0.05	0.01	0.06		13.4	344	37.3	77.6
131	Turkey L. (4)	det.	det.	det.	0.02			11.5	91.8
132	Turkey L. (5)	0.08	det.						
133	St. Marys R. at Sault Ste. Marie (1)				0.01				22.0
134	St. Marys R. at Sault Ste. Marie (2)	1.68	0.09					5.2	57.8

Table 1 cont'd

No.	Location	Subsurface				Microlayer			
		Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin	Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin
136	Blind R.	0.57	det.		0.01				25.2
137	Elliot L.	det.		0.01	0.56				
138	Spanish R.		det.	det.	0.31				
139	Georgian Bay	det.			0.49	4.8	4.6	16.4	46.0
140	Simon L.	det.			0.50				31.2
141	Kelley L.		det.		1.60			2.7	56.8
142	Ramsey L.	0.02	det.	det.	4.69		19.4	2.9	
143	Elbow L.								
144	Nepewassi L.	0.04	0.01	0.01	1.36				
145	Ashigami L.		0.93	0.03	0.17				
146	Kukagami L.				0.72				88.0
148	L. Muskoka	0.04			0.02				40.6
149	Collingwood Harbour				1.84		184	12.2	
156	St. Clair R. (3)	0.22		0.03	0.04			8.0	29.5
158	St. Clair R. (5)			0.01	1.11			22.2	168
162	Thames R.				0.44			6.2	158
167	Port Stanley	0.29	0.20	1.89	27.2			3.9	49.3
169	Nanticoke				1.72				
171	Grand R. (2)				0.04				
174	Niagara R. at Fort Erie				0.07				
175	Niagara R., Chippawa Channel								

Table 1 cont'd

No.	Location	Subsurface				Microlayer			
		Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin	Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin
176	Niagara R. at Niagara-on-the-Lake (1)				0.08	7.70			
177	Niagara R. at Niagara-on-the-Lake (2)				0.06				
183	Port Weller	det.			1.21			26.7	1330
184	Credit R.	0.03	det.			6.60	2.60	16.4	63.6
185	Humber R.	det.			0.34	2.90	2.40	4.20	73.3
186	Toronto Harbour (1)					5.20		31.5	4.90
187	Toronto Harbour (2)	0.03	0.01	0.59	6.46	6.30	1.80	25.3	143
188	Don R.								
189	Toronto Harbour (3)	0.24	0.01	0.11	2.00	9.80	4.10	34.3	14000
190	Whitby (1)	1.72	0.74	0.42	37.2			1.70	199
191	Whitby (2)	0.10	0.06	0.01	3.04	7.10	6.00	26.4	
194	Moira L.				0.42	3.60		66.8	126
195	Moira R.	0.01			0.27				
196	Belleville	0.01	1.36		0.55	473		10.7	11000
198	St. Lawrence R. at Maitland (1)	0.05		0.01	0.83	2.20		8.10	63.9
199	St. Lawrence R. at Maitland (2)				1.32	12.4	22.5	34.6	1400
200	St. Lawrence R. at Cornwall (1)	0.01			0.34	1.90		15.4	17.8
201	St. Lawrence R. at Cornwall (2)				0.19	4.50	1.80	18.7	

Table 1 cont'd

No.	Location	Subsurface				Microlayer			
		Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin	Bu_3Sn^+	Bu_2Sn^{2+}	$BuSn^{3+}$	Tin
206	Ottawa R. at Chalk River	0.52	0.02						21.8
207	Ottawa R. at Arnprior				0.23	3.30	9.90	28.4	1700
208	Ottawa R. at Ottawa				0.32			13.5	220
NEW YORK STATE, USA									
211	Buffalo Harbor				0.08	23.8			
212	Buffalo R.		0.01	0.02	5.50			5.80	43.0
213	Niagara R. (1)				1.06				
214	Niagara R. (2)					4.10	5.90	0.10	
215	Gill Creek					4.60	7.00	25.1	
216	Niagara R. (3)			1.82	0.07	2.00		20.4	37.4
QUEBEC									
217	Ottawa R. at Temiscaming						97.4	46.7	100
219	Ottawa R. at Thurso	det.			2.36		4.80	27.2	1040
220	Ottawa R. at Montebello	0.02			0.06	5.50		34.1	56.1
229	Canal de la Rive Sud								1600
231	St. Lawrence R. at Montreal (1)	0.03	0.07	0.04	4.70			23.3	296
232	St. Lawrence R. at Montreal (2)			0.42	0.71	15.2		18.2	115
235	Montreal Harbour (1)	det.		0.62	0.21			13.5	

Table 1 cont'd

*Location numbers correspond to those shown in Maguire et al. 1986, from which the concentrations in subsurface water are taken. Precise sampling locations are shown in the Appendix. "Blanks" mean below limit of detection (LOD - Keith et al. 1983) and "det." means that a species was detected but its concentration was below the limit of quantitation (LOQ - Keith et al. 1983). For sample sizes of 8 L for subsurface water and 100 mL for the surface microlayer, the LOQ values for each species are about 0.01 and 1.0 ug Sn/L, respectively. LOD values were generally about one third of LOQ values.

Table 2. Ratios of Concentrations and Ratios of Amounts of Bu_3Sn^+ in the Surface Microlayer and Subsurface Water*

No.	Location	Concentration in microlayer / Concentration in subsurface	Amount in microlayer / Amount in subsurface
119	Thunder Bay (1)	2.09×10^{3}	6.27×10^{-2}
130	Turkey L. (3)	2.68×10^{2}	4.02×10^{-3}
184	Credit R.	2.20×10^{2}	8.80×10^{-3}
187	Toronto Harbour (2)	2.10×10^{2}	1.26×10^{-3}
189	Toronto Harbour (3)	4.08×10^{1}	2.33×10^{-4}
191	Whitby (2)	7.10×10^{1}	6.08×10^{-4}
196	Belleville	4.73×10^{4}	7.09×10^{-1}
198	St. Lawrence R. at Maitland (1)	4.40×10^{1}	1.32×10^{-3}
200	St. Lawrence R. at Cornwall (1)	1.90×10^{2}	4.56×10^{-3}
220	Ottawa R. at Montebello	2.75×10^{2}	1.65×10^{-2}

*Only for those locations at which Bu_3Sn^+ was determined reliably (i.e., above LOQ) in both compartments.

Table 3. Ratios of Concentrations and Ratios of Amounts of Bu_2Sn^{2+} in the Surface Microlayer and Subsurface Water*

No.	Location	Concentration in microlayer / Concentration in subsurface	Amount in microlayer / Amount in subsurface
119	Thunder Bay (1)	1.89×10^{3}	5.68×10^{-2}
130	Turkey L. (3)	3.44×10^{4}	5.16×10^{-1}
187	Toronto Harbour (2)	1.80×10^{2}	1.08×10^{-3}
189	Toronto Harbour (3)	4.10×10^{2}	2.34×10^{-3}
191	Whitby (2)	1.00×10^{2}	8.57×10^{-4}

*Only for those locations at which Bu_2Sn^{2+} was determined reliably (*i.e.*, above LOQ) in both compartments.

Table 4. Ratios of Concentrations and Ratios of Amounts of $BuSn^{3+}$ in the Surface Microlayer and Subsurface Water*

No.	Location	Concentration in microlayer / Concentration in subsurface	Amount in microlayer / Amount in subsurface
130	Turkey L. (3)	6.22×10^{2}	9.33×10^{-3}
156	St. Clair R. (3)	2.67×10^{2}	5.34×10^{-3}
158	St. Clair R. (5)	2.22×10^{3}	1.02×10^{-2}
167	Port Stanley	2.06	1.76×10^{-5}
187	Toronto Harbour (2)	4.29×10^{1}	2.57×10^{-4}
189	Toronto Harbour (3)	3.12×10^{2}	1.78×10^{-3}
190	Whitby (1)	4.05	8.10×10^{-5}
191	Whitby (2)	2.64×10^{3}	2.26×10^{-2}
198	St. Lawrence R. at Maitland (1)	8.10×10^{2}	2.43×10^{-2}
212	Buffalo R.	2.90×10^{2}	1.34×10^{-3}
216	Niagara R. (3)	1.12×10^{1}	1.92×10^{-4}
231	St. Lawrence R. at Montreal (1)	5.82×10^{2}	4.36×10^{-3}
232	St. Lawrence R. at Montreal (2)	4.33×10^{1}	8.66×10^{-4}
235	Montreal Harbour (1)	2.18×10^{1}	1.31×10^{-4}

*Only for those locations at which $BuSn^{3+}$ was determined reliably (i.e., above LOQ) in both compartments.

Table 5. Ratios of Concentrations and Ratios of Amounts of Tin in the Surface Microlayer and Subsurface Water*

No.	Location	Concentration in microlayer / Concentration in subsurface	Amount in microlayer / Amount in subsurface
119	Thunder Bay (1)	8.96	2.69×10^{-4}
122	Kaministiquia R.	4.36×10^{2}	3.74×10^{-3}
127	Marathon (3)	6.25×10^{1}	5.36×10^{-4}
128	Turkey L. (1)	1.28×10^{3}	6.40×10^{-3}
131	Turkey L. (4)	4.59×10^{3}	1.53×10^{-2}
133	Saint Marys R. at Sault Ste. Marie (1)	2.20×10^{3}	2.64×10^{-2}
136	Blind R.	2.52×10^{3}	5.04×10^{-2}
139	Georgian Bay	9.39×10^{1}	5.12×10^{-4}
140	Simon L.	6.24×10^{1}	6.24×10^{-4}
141	Kelley L.	3.55×10^{1}	3.04×10^{-4}
146	Kukagami L.	1.22×10^{2}	1.46×10^{-3}
148	L. Muskoka	2.03×10^{3}	6.09×10^{-3}
156	St. Clair R. (3)	7.37×10^{2}	1.47×10^{-2}
158	St. Clair R. (5)	1.51×10^{2}	6.97×10^{-4}
162	Thames R.	3.59×10^{2}	6.15×10^{-3}
167	Port Stanley	1.81	1.55×10^{-5}
183	Port Weller	1.10×10^{3}	6.29×10^{-3}
185	Humber R.	2.15×10^{2}	8.60×10^{-3}
187	Toronto Harbour (2)	2.21×10^{1}	1.33×10^{-4}
189	Toronto Harbour (3)	7.00×10^{3}	4.12×10^{-2}
190	Whitby (1)	5.35	1.07×10^{-4}
194	Moira L.	3.00×10^{2}	3.60×10^{-3}

Table 5 cont'd

No.	Location	Concentration in microlayer / Concentration in subsurface	Amount in microlayer / Amount in subsurface
196	Belleville	2.00×10^{4}	3.00×10^{-1}
198	St. Lawrence R. at Maitland (1)	7.70×10^{1}	2.31×10^{-3}
199	St. Lawrence R. at Maitland (2)	1.06×10^{3}	3.18×10^{-2}
200	St. Lawrence R. at Cornwall (1)	5.23×10^{1}	1.26×10^{-3}
207	Ottawa R. at Arnprior	7.39×10^{3}	8.06×10^{-2}
208	Ottawa R. at Ottawa	6.87×10^{2}	1.37×10^{-2}
212	Buffalo R.	7.82	3.61×10^{-5}
216	Niagara R. (3)	5.34×10^{2}	9.15×10^{-3}
219	Ottawa R. at Thurso	4.41×10^{2}	6.61×10^{-3}
221	Ottawa R. at Montebello	9.35×10^{2}	1.87×10^{-2}
231	St. Lawrence R. at Montreal (1)	6.30×10^{1}	4.72×10^{-4}
232	St. Lawrence R. at Montreal (2)	1.62×10^{2}	3.24×10^{-3}

*Only for those locations at which tin was determined reliably (i.e., above LOQ) in both compartments.

Appendix. Details of Sampling Locations

No.	Location	Details	Depth, m	Date
BRITISH COLUMBIA				
1	Nanaimo Harbour	at Beacon Rock	8.4	1984/10
2	Tsehun Harbour	at North Saanich Marina, Vancouver Island	6	1984/10/19/a.m.
3	Deep Cove	Saanich Inlet, Vancouver Island	12	1984/10/19/a.m.
4	Patricia Bay	Saanich Inlet, Vancouver Island. Off wharf at Institute of Ocean Sciences	10	1984/10/11/14:00
5	Esquimalt Harbour (1)	in Plumper Bay north of Inskip Islands	10.5	1984/10
6	Esquimalt Harbour (2)	in Constance Cove off Village Rocks	12.9	1984/10
7	Victoria Harbour (1)	Inner Harbour, half way between Shoal Point and Songhees Point	8.4	1984/10/17
8	Victoria Harbour (2)	Upper Harbour, off Hope Point	9	1984/10/17
9	Vancouver Harbour (1)	Burrard Inlet at First Narrows, off sewage treatment plant west of Lions Gate Bridge	6	1984/10
10	Vancouver Harbour (2)	Vancouver Wharves	13.5	1984/8/20/09:50
11	Vancouver Harbour (3)	Vancouver Wharves	6	1984/8/20/09:58
12	Vancouver Harbour (4)	Vancouver Wharves	10	1984/8/20/10:05
13	Vancouver Harbour (5)	L&K Lumber, 15 m from shore	6	1984/8/20/10:12
14	Vancouver Harbour (6)	L&K Lumber, 30 m from shore	10	1984/8/20/10:20
15	Vancouver Harbour (7)	L&K Lumber, 100 m from shore	10	1984/8/20/10:30
16	Vancouver Harbour (8)	L&K Lumber, off loading facility	30	1984/8/20/10:45
17	Vancouver Harbour (9)	Vancouver Shipyards	5	1984/10
18	Vancouver Harbour (10)	Vancouver Shipyards/Seaspan, 10 m from inner dock	8	1984/8/20/11:30
19	Vancouver Harbour (11)	Vancouver Shipyards/Seaspan, 100 m from dock	8	1984/8/20/11:30

Appendix cont'd

No.	Location	Details	Depth, m	Date
20	Vancouver Harbour (12)	Burrard Yarrows Corp.	7	1984/10
21	Vancouver Harbour (13)	Burrard Yarrows Corp.	9	1984/8/20/11:50
22	Vancouver Harbour (14)	Burrard Yarrows Corp.	11	1984/8/20/12:00
23	Vancouver Harbour (15)	Burrard Yarrows Corp.	24	1984/8/20/12:10
24	Vancouver Harbour (16)	White Pass Transport Ltd.	6	1984/8/20/12:20
25	Vancouver Harbour (17)	Neptune Terminals	15	1984/8/20/12:35
26	Vancouver Harbour (18)	Neptune Terminals	20	1984/8/20/12:40
27	Vancouver Harbour (19)	Neptune Terminals	18	1984/8/20/12:45
28	Vancouver Harbour (20)	Neptune Terminals	30	1984/8/20/12:50
29	Vancouver Harbour (21)	Lynnterm	19	1984/8/20/13:00
30	Vancouver Harbour (22)	Bel Aire Shipyards	8	1984/8/20/14:00
31	Vancouver Harbour (23)	Bel Aire Shipyards	3	1984/10
32	Vancouver Harbour (24)	Allied Shipbuilders	8	1984/8/20/14:20
33	Vancouver Harbour (25)	Matsumoto Shipyards Ltd.	8.5	1984/8/20/14:40
34	Vancouver Harbour (26)	RivTow Straits	20	1984/8/20/15:00
35	Vancouver Harbour (27)	Sterling Shipyards	2	1984/8/20/15:25
36	Vancouver Harbour (28)	Sterling Shipyards	3	1984/10
37	Vancouver Harbour (29)	B.C. Marine Shipbuilders	4	1984/10
38	Vancouver Harbour (30)	B.C. Marine Shipbuilders	3	1984/8/20/15:40
39	Vancouver Harbour (31)	Vanterm	19	1984/8/20/15:45
40	Vancouver Harbour (32)	National Harbours Board, Pier B.C.	17	1984/8/20/16:10
41	Vancouver Harbour (33)	W.R. Menchions Shipyard, 30 m from shore	7	1984/8/20/16:20
42	Vancouver Harbour (34)	W.R. Menchions Shipyard, 60 m from shore	7.5	1984/8/20/16:30

Appendix cont'd

No.	Location	Details	Depth, m	Date
43	Vancouver Harbour (35)	W.R. Menchions Shipyard, 100 m from shore	9	1984/8/20/16:40
44	Vancouver Harbour (36)	between Gulf and Esso gasoline barges off Deadman Island	7	1984/10
45	False Creek	200 m east of Burrard Bridge	4	1984/10
46	Fraser R. (1)	North Arm, off sewage treatment plant at Iona Island	6	1984/10
47	Fraser R. (2)	North Arm, off Celtic Shipyards	6	1984/10
48	Fraser R. (3)	North Arm, off Celtic Shipyards	4	1984/8/23/11:25
49	Fraser R. (4)	North Arm, 100 m downstream of Arthur Laing Bridge	6	1984/10
50	Fraser R. (5)	North Arm, Breezedale Marina	4.5	1984/8/23/11:00
51	Fraser R. (6)	North Arm, south of Mitchell Island, off Quadra Steel	5	1984/10
52	Fraser R. (7)	North Arm, John Manly Shipyard	4	1984/8/23/10:25
53	Fraser R. (8)	North Arm, John Manly Shipyard	5	1984/8/23/10:20
54	Fraser R. (9)	North Arm, John Manly Shipyard	4	1984/10
55	Fraser R. (10)	North Arm, Fraser Marine Group	5	1984/8/23/10:10
56	Fraser R. (11)	North Arm, off Tom Mac Shipyard	6	1984/10
57	Fraser R. (12)	North Arm, Tom Mac Shipyard, at entrance to river	5	1984/8/23/09:55
58	Fraser R. (13)	North Arm, Tom Mac Shipyard, in dock area	4	1984/8/23/09:55
59	Fraser R. (14)	North Arm, off Byrne Road	9	1984/10
60	Fraser R. (15)	North Arm, north of Poplar Island, off Scott Paper	2	1984/10
61	Fraser R. (16)	off Pacific Coast Terminals	9	1984/8/22/15:00
62	Fraser R. (17)	Annacis Channel, off sewage treatment plant	2	1984/10
63	Fraser R. (18)	Annacis Channel, Marine Fabrication Repair	3	1984/8/22/14:15
64	Fraser R. (19)	Annacis Channel, Queensborough Shipyard	6	1984/8/22/13:45
65	Fraser R. (20)	Annacis Channel, S.B. Shore Boat Builders	6	1984/8/22/13:30

Appendix cont'd

No.	Location	Details	Depth, m	Date
66	Fraser R. (21)	Annacis Channel, at dock of Stem to Stern Boat Repair	4	1984/8/22/12:20
67	Fraser R. (22)	Annieville Channel, Annacis Marine Terminal	13	1984/8/22/14:30
68	Fraser R. (23)	Annieville Channel, Surrey Dock	11	1984/8/22/14:35
69	Fraser R. (24)	Annieville Channel, Gundersen Slough	4	1984/10
70	Fraser R. (25)	City Reach, Vito Shipbuilding	11	1984/8/22/11:40
71	Fraser R. (26)	Gravesend Reach, West Bay Boat Builders	3	1984/10
72	Fraser R. (27)	Gravesend Reach, West Bay Boat Builders, 20 m from shore	4	1984/8/22/11:20
73	Fraser R. (28)	south of Deas Island, at marina	2	1984/10
74	Fraser R. (29)	Woodward Reach, B.C. Ferries, middle berth, 30 m from shore	4	1984/8/22/10:15
75	Fraser R. (30)	Woodward Reach, B.C. Ferries, middle of channel	6	1984/8/22/10:30
76	Fraser R. (31)	Woodward Reach, B.C. Ferries, between channel markers	4	1984/8/22/10:35
77	Fraser R. (32)	Cannery Channel, off Esso	4	1984/10
78	Okanagan L. at Penticton	off Riverside Park	3	1984/10
79	Okanagan R. at Penticton	at Greenwood Forest Products	1	1984/10
ALBERTA				
80	North Saskatchewan R. at Devon (1)	at Hwy. 60 bridge		1983/6
81	North Saskatchewan R. at Devon (2)	at Hwy. 60 bridge	1	1984/10

Appendix cont'd

No.	Location	Details	Depth, m	Date
82	North Saskatchewan R. at Edmonton	south side of river, off 50th Street	1	1984/10
83	North Saskatchewan R. above Fort Saskatchewan	at Hwy. 25 bridge	1	1984/10
84	North Saskatchewan R. at Fort Saskatchewan (1)	at 119th Street	1	1984/10
85	North Saskatchewan R. at Fort Saskatchewan (2)	at 119th Street		1983/6
86	North Saskatchewan R. below Fort Saskatchewan	3 km downstream, close to intersection of Township Road 554 and Range Road 221	1	1984/10
87	North Saskatchewan R. at Pakan			1983/6
88	North Saskatchewan R. near Myrnam			1983/6
89	North Saskatchewan R. near Alcurve			1983/6
90	Bow R. above Calgary	immediately upstream of Bowness Park	1	1984/10
91	Bow R. at Calgary	below Prince's Island	1	1984/10
92	Bow R. below Calgary	500 m downstream of Hwy. 22 bridge	1	1984/10

Appendix cont'd

No.	Location	Details	Depth, m	Date
93	Oldman R. at Lethbridge	at Whoop-Up Trail Road bridge	1	1984/10
94	South Saskatchewan R. at Medicine Hat	upstream of Hwy. 1 bridge	1	1984/10
SASKATCHEWAN				
95	North Saskatchewan R. at North Battleford (1)	at Hwy. 16 bridge		1983/6
96	North Saskatchewan R. at North Battleford (2)	at Hwy. 16 bridge	1	1984/10/29/14:30
97	North Saskatchewan R. near Borden			1983/6
98	North Saskatchewan R. at Prince Albert (1)	upstream of Hwy. 2 bridge and railway bridge		1983/6
99	North Saskatchewan R. at Prince Albert (2)	upstream of Hwy. 2 bridge and railway bridge	1	1984/10/30/10:45
100	South Saskatchewan R. at Saskatoon	upstream of 42nd Street bridge	1	1984/10/30/16:15
101	South Saskatchewan R. below Saskatoon	at Hwy. 784 ferry crossing	1	1984/10/30/15:00
102	Qu'Appelle R. at Fort Qu'Appelle	at Hwy. 10 bridge	1	1984/11/14/10:15
103	Qu'Appelle R. near Welby	at Hwy. 600 bridge	1	1984/10/15/12:00
104	Wascana Cr. at Regina	downstream of Regina sewage treatment plant	1	1984/11/14/12:45

Appendix cont'd

No.	Location	Details	Depth, m	Date
105	Saskatchewan R. at Nipawin			1983/6
MANITOBA				
106	Saskatchewan R. at The Pas	downstream of Hwy. 10 bridge and railway bridge	1	1984/10/18/09:25
107	Souris R. at Coulter	at Hwy. 251 bridge	1	1984/10/25/13:45
108	Red R. at Selkirk	at Hwy. 204 bridge	1	1984/10/18/13:15
109	Red. R. above Winnipeg	at Hwy. 101 perimeter north bridge	1	1984/10/18/12:00
110	Red R. below Winnipeg	at Hwy. 101 perimeter south bridge	2	1984/10/10/15:00
111	Red R. at Emerson	at Hwy. 25 bridge	1	1984/10
ONTARIO				
112	Wabigoon R. at Dryden	50 m downstream of Great Lakes Forest Products mill	4	1982/7
113	Wabigoon R. at Minnitaki	off bridge	3	1982/7
114	Wabigoon R. (1)	at Hwy. 105 bridge	4	1982/7
115	Wabigoon R. (2)	entrance to Clay L.	2	1982/7
116	Clay L. (1)	middle	9	1982/7
117	Clay L. (2)	north arm	5	1982/7
118	Wabigoon R. (3)	downstream of Clay L. at Canyon R. falls	8	1982/7
119	Thunder Bay (1)	30 m offshore from Northern Wood Preservers Co.	2	1982/7
120	Thunder Bay (2)	50 m off filtration beds at Abitibi Paper Co.	1	1982/7
121	Thunder Bay (3)	1 km north of Mission Bay	3	1982/7
122	Kaministiquia R.	river mouth	7	1982/7

Appendix cont'd

No.	Location	Details	Depth, m	Date
123	Nipigon R.	1 km downstream of Red Rock, in effluent of pulp mill	11	1982/7
124	Terrace Bay	in effluent flowing from pupl and paper mill	1	1982/7
125	Marathon (1)	in effluent of American Can Co.	2	1982/7
126	Marathon (2)	in effluent of American Can Co.	4	1982/7
127	Marathon (3)	10 m off wharf at American Can Co.	7	1982/7
128	Turkey L. (1)	middle	12	1982/7
129	Turkey L. (2)	middle	10	1982/7
130	Turkey L. (3)	middle	4	1982/7
131	Turkey L. (4)	middle	18	1982/7
132	Turkey L. (5)	middle	8	1982/7
133	St. Marys R. at Sault Ste. Marie (1)	in power canal 100 m downstream of Huron St.	5	1982/7
134	St. Marys R. at Sault Ste. Marie (2)	at entrance to Algoma Steel Corp. slip	5	1982/7
135	St. Marys R. at Sault Ste. Marie (3)	200 m offshore from Ontario Ministry of Natural Resources building	5	1982/7
136	Blind R.	downstream of effluent pipes of El Dorado Nuclear Ltd.	3	1982/7
137	Elliot L.	middle	10	1982/7
138	Spanish R.	at Espanola, beneath bridge on Hwy. 6	3	1982/7
139	Georgian Bay	at Little Current, Manitoulin Island, in shipping channel 50 m from railway bridge	11	1982/7
140	Simon L.	southwest of Sudbury, middle of lake	6	1982/7
141	Kelley L.	southwest of Sudbury, middle of lake	7	1982/7

Appendix cont'd

No.	Location	Details	Depth, m	Date
142	Ramsey L.	in Sudbury, northeast of McNaughton Island	18	1982/7
143	Elbow L.	southeast of Sudbury, middle of lake	9	1982/7
144	Nepewassi L.	southeast of Sudbury, middle of lake	6	1982/7
145	Ashigami L.	northeast of Sudbury, extreme western arm	4	1982/7
146	Kukagami L.	northeast of Sudbury, middle of west arm	5	1982/7
147	L. Nipissing at North Bay	100 m off public wharf	5.5	1982/7
148	L. Muskoka	water collected 100 m off Kennedy Point, sediment collected in middle of Milford Bay	20	1982/7
149	L. Simcoe at Barrie	Kempenfelt Bay, 500 m off Big Bay Point lighthouse	7.5	1982/7
150	Collingwood Harbour	middle of harbour	6	1982/7
151	Owen Sound Harbour	mouth of Sydenham R.	8	1982/7
152	L. Huron (1)	at Baie du Dore at Douglas Point	3	1982/7
153	L. Huron (2)	head of St. Clair R.	4	1982/7
154	St. Clair R. (1)	in Sarnia, 1 km downstream of Reid Aggregates Ltd.	5	1982/7
155	St. Clair R. (2)	above Corunna, near outflow of Ethyl Corp.	2	1982/7
156	St. Clair R. (3)	at Corunna, 200 m off Hill St.	3	1982/7
157	St. Clair R. (4)	south channel at Harsens Island	5	1982/7
158	St. Clair R. (5)	south channel at Southeast Bend	13	1982/7
159	L. St. Clair (1)	south of Seaway Island	1	1982/7
160	L. St. Clair (2)	off entrance to shipping channel in St. Clair R.	18	1982/7
161	L. St. Clair (3)	marina in Mitchell Bay	2	1982/7
162	Thames R.	mouth	3.5	1982/7
163	Detroit R. (1)	downstream of Belle Isle, at Hiram Walker & Sons, Ltd.	9	1982/7

Appendix cont'd

No.	Location	Details	Depth, m	Date
164	Detroit R. (2)	east of Fighting Island, north of Turkey Island	10	1982/7
165	L. Erie (1)	middle of western basin	10	1982/7
166	L. Erie (2)	middle of eastern basin	20	1982/7
167	Port Stanley	middle of zone "b", inside breakwater	7	1982/7
168	Port Dover	15 m off lighthouse, at entrance to harbour	4	1982/7
169	Nanticoke	50 m off Ontario Hydro plant	8	1982/7
170	Grand R. (1)	at bridge at Lancaster	2	1982/7
171	Grand R. (2)	lagoon in sewage treatment plant at Kitchener	2	1982/7
172	Grand R. (3)	20 m downstream of sewage treatment plant at Kitchener	2	1982/7
173	Grand R. (4)	mouth of river at Port Maitland, 400 m downstream of fertilizer plant	5	1982/7
174	Niagara R. at Fort Erie	300 m upstream of Peace Bridge	7.5	1982/7
175	Niagara R., Chippawa Channel	between Navy Island and Ontario shore	3.5	1982/7
176	Niagara R. at Niagara-on-the-Lake (1)	middle	17	1982/7
177	Niagara R. at Niagara-on-the-Lake (2)	middle	17	1983/6
178	Welland Canal (1)	at entrance to canal in Port Colborne	13	1982/7
179	Welland Canal (2)	at Thorold, 50 m upstream of lock 7	10	1982/7
180	Thorold South	in drainage ditch (which is a tributary of L. Gibson) near Beaver Wood Fibre Ltd.	3	1982/7

Appendix cont'd

No.	Location	Details	Depth, m	Date
181	St. Catharines (1)	Old Welland Canal spillway near corner of Merritt St. and Glendale Rd.	8	1982/7
182	St. Catharines (2)	confluence of Twelve Mile Creek and Old Welland Canal spillway	7	1982/7
183	Port Weller	middle of dry dock area	10.5	1982/7
184	Credit R.	mouth	1.5	1982/7
185	Humber R.	mouth	1.5	1982/7
186	Toronto Harbour (1)	middle of Western Gap	12	1982/7
187	Toronto Harbour (2)	Centre Island Ferry lane	10	1982/7
188	Don R.	mouth	7	1982/7
189	Toronto Harbour (3)	middle of eastern shipping channel	10.5	1982/7
190	Whitby (1)	off Whitby Yacht Club near Hulk	3	1982/7
191	Whitby (2)	in area "b", 10 m off Texaco tank farm	7	1982/7
192	Port Hope	Ganaraska R., south of El Dorado Nuclear Ltd.	3.5	1982/7
193	Cobourg	in harbour, 100 m east of Cobourg Yacht Club	6	1982/7
194	Moira L.	center of western basin	5	1982/7
195	Moira R.	middle of Ben Bay	3	1982/7
196	Belleville	mouth of Moira R.	4	1982/7
197	Kingston Harbour	mouth of Cataraqui R., 100 m downstream of Hwy. 2 bridge	5	1982/7
198	St. Lawrence R. at Maitland (1)	downstream of DuPont Ltd. effluent pipe	2	1982/7
199	St. Lawrence R. at Maitland (2)	middle of Blue Church Bay	2	1982/7

Appendix cont'd

No.	Location	Details	Depth, m	Date
200	St. Lawrence R. at Cornwall (1)	500 m downstream of CIL Ltd. effluent	2.5	1982/7
201	St. Lawrence R. at Cornwall (2)	middle of river, 50 m downstream of Seaway International Bridge	2.5	1982/7
202	St. Lawrence R. at Cornwall (3)	south of Cornwall Island	2	1984/10
203	St. Lawrence R. at Cornwall (4)	at Marina Co-operative de Cornwall	2.5	1984/10
204	L. Timiskaming	at Haileybury, 200 m south of Rexway Plywood	17	1982/7
205	Sasaginaga L.	at Cobalt, 5 m off tailings ponds	0.5	1982/7
206	Ottawa R. at Chalk River	50 m downstream of Atomic Energy of Canada Ltd., 15 m off shore	5.5	1982/7
207	Ottawa R. at Arnprior	2 km downstream of mouth of Madawaska R., 20 m from shore	5.5	1982/7
208	Ottawa R. at Ottawa	middle of river, 500 m downstream of Chaudiere Falls	3	1982/7
209	Ottawa R. at Chute a Blondeau	off public wharf	1.5	1984/10
MICHIGAN, USA				
210	Detroit R.	downstream of Belle Isle, 50 m off Medusa Cement Co.	8	1982/7
NEW YORK STATE, USA				
211	Buffalo Harbor	15 m off Bethlehem Steel Co.	11	1983/6
212	Buffalo R.	mouth	13	1983/6
213	Niagara R. (1)	Tonawanda Channel, at mouth of Erie Canal	3.5	1983/6

Appendix cont'd

No.	Location	Details	Depth, m	Date
214	Niagara R. (2)	Tonawanda Channel at 102nd St. dump, 10 m off shore	0.2	1983/6
215	Gill Creek	mouth of creek, Niagara Falls, N.Y.	1	1983/6
216	Niagara R. (3)	100 m below Gill Creek mouth, 50 m off shore	3.5	1983/6
QUEBEC				
217	Ottawa R. at Temiscaming	1 km downstream of bridge to Thorne	9	1982/7
218	Schyan R.	mouth	3	1982/7
219	Ottawa R. at Thurso	300 m upstream of ferry dock, 10 m off shore	4	1982/7
220	Ottawa R. at Montebello	in bay at mouth of Ruisseau Papineau	1	1982/7
221	Lac des Deux Montagnes	in Anse de Vaudreuil, off Club Nautique Deux Montagnes	3	1984/8/20
222	Lac Saint-Louis (1)	at Sainte-Anne-de-Bellevue, upstream of lock	4	1984/8/20
223	Lac Saint-Louis (2)	2 km north of Riv. St.-Louis, 0.5 km west of Iles de la Paix	8	1984/8/20
224	Lac Saint-Louis (3)	0.5 km east of mouth of Riv. St.-Louis	3	1984/8/28
225	Lac Saint-Louis (4)	at Marina Iroquois, Lachine	4	1984/8/20
226	Sainte-Catherine lock	between lock and No. 2 turning basin	4.5	1984/8/21
227	Saint-Lambert lock (1)	upstream of bridge No. 3	9	1984/8/21
228	Saint-Lambert lock (2)	downstream of Victoria Bridge	6.5	1984/8/21
229	Canal de la Rive Sud	800 m downstream of Victoria Bridge	18	1982/7
230	St. Lawrence R. at Longueuil	at Longueuil Yacht Club	5	1982/7
231	St. Lawrence R. at Montreal (1)	between oil tank farms and Ile Dufault, 10 m off shore	8	1982/7

Appendix cont'd

No.	Location	Details	Depth, m	Date
232	St. Lawrence R. at Montreal (2)	between oil tank farms and Ile Dufault, 10 m off shore	3	1982/7
233	St. Lawrence R. at Montreal (3)	at wharf at end of St.-Jean-Baptiste Blvd., Pointe-aux-Trembles	5	1984/8/21
234	St. Lawrence R. at Montreal (4)	at Marina Jean Beaudoin, east end of Montreal Island	1.5	1984/8/21
235	Montreal Harbour (1)	Pointe du Moulin a Vent, 15 m off shore	10	1982/7
236	Montreal Harbour (2)	middle of quai No. 2 between Pointe du Moulin a Vent and Alexandra Pier	13	1984/8/23
237	Montreal Harbour (3)	middle of quai No. 11 between King Edward Pier and Jacques-Cartier Pier	14	1984/8/23
238	Montreal Harbour (4)	middle of Market Basin	9.5	1984/8/23
239	Montreal Harbour (5)	at end of Jetty No. 3	13.5	1984/8/23
240	Montreal Harbour (6)	at end of Vickers Ltd. floating docks	9	1984/8/23
241	Richelieu R. at St.-Jean d'Iberville	upstream of Hwy. 35 bridge	4	1984/8/16
242	Richelieu R. at Ville-de-Tracy	at Marine Industries Ltd.	8	1984/10/25/11:00
243	St. Francois R.	mouth	4.5	1984/10/25
244	St. Lawrence R. at Quebec (1)	middle of marina near St. Lawrence Tankers	8	1984/8/30
245	St. Lawrence R. at Quebec (2)	at Queen's Wharf	9.5	1984/8/30

Appendix cont'd

No.	Location	Details	Depth, m	Date
246	Louise Basin at Quebec	middle	9.5	1984/8/30
NEW BRUNSWICK				
247	Saint John R. at Quisibis	0.5 km above La Grande Isle	1	1984/10
248	Saint John R. at Maugerville	1 km below Oromocto Island	4	1984/10
249	Kennebecasis Bay at Renforth	1 km north of Renforth Cove. Ice 1 m thick.	17.5	1985/2/4/11:50
250	Saint John Harbour	half way between Ministry of Transport pier and Pugsley Terminal, 10 m from shore	12	1985/2/4/14:00
251	Dalhousie Harbour	at end of New Brunswick International Paper wharf	10	1985/2/6/12:30
252	Bathurst Harbour	between Middle River Causeway and yacht club in West Bathurst	1.5	1985/2/6/16:00
253	Lameque Harbour	near inlet to old wharf enclosure	5	1981/8/25
254	Shippegan Harbour	15 m inside southerly wharf enclosure	6	1981/8
255	Miramichi R. (1)	in cove at Douglastown, 1.7 km above Hwy. 11 bridge	0.3	1985/2/5/15:00
256	Miramichi R. (2)	at Millbank, off Government Wharf	9	1985/2/5/16:00
257	Escuminac Harbour	100 m inside wharf enclosure	2.5	1981/8
258	Point Sapin	50 m inside wharf enclosure	2.5	1981/8
259	Richibucto Harbour	inside Government Wharf enclosure	2	1985/2/7/11:30
260	Cap Lumiere	in outlet of wharf enclosure	2.5	1981/8
261	Chockpish R.	50 m inside wharf enclosure	2.5	1981/8

Appendix cont'd

No.	Location	Details	Depth, m	Date
262	St. Edouard de Kent	inside harbour, 50 m from end of wharf	2	1981/8
263	Buctouche Harbour	in small bay close to Irving Oil tanks	1	1985/2/7/14:00
264	Shediac Bay	at Pointe-du-Chene, 50 m from south side of wharf	3.5	1985/2/7/16:30
265	Cap Pele	L'Abiteau wharf enclosure, 50 m from outlet	2	1981/8
266	Murray Corner	at wharf at outlet to Northumberland Strait	1.5	1981/8
267	Cape Tormentine	at "Fisherman's Wharf" enclosure, 50 m from northeast corner	4	1981/8
PRINCE EDWARD ISLAND				
268	Charlottetown Harbour	off Department of Transport Marine Terminal	5	1984/10
NOVA SCOTIA				
269	Pictou Harbour	between Town Point and Battery Point	13	1984/11/28/15:00
270	Port Hawkesbury Harbour	mouth of harbour	8	1984/11/28/11:00
271	Sydney Harbour	middle of channel, north of Shingle Point	16	1984/11/27/14:00
272	Halifax Harbour	middle of Eastern Passage, off Baker Point	16	1984/11/26/15:00
NEWFOUNDLAND				
273	Port-aux-Basques Harbour	half way between Scotts Point and Point Pleasant	3	1984/11
274	Stephenville Pond	inside entrance to Pond from St. George's Bay	9	1984/11
275	Argentia Harbour	at marina between Sandy Cove and Cooper Cove	2	1984/11
276	Conception Bay	middle of Long Pond on Belle Island, north of Topsail Yacht Club	15	1984/11
277	St. John's Harbour	at Pier 2	11	1984/11